RAPID COMMUNICATION

Breath-by-Breath Oxygen Consumption During Performance of the Wingate Test

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ABSTRACT

The aerobic contribution to the Wingate Anaerobic Power Test (WAnT) was evaluated by measuring breath-by-breath oxygen consumption ($\dot{V}O_2$) in five male subjects. Assuming an optimal mechanical efficiency, net $\dot{V}O_2$ during the WAnT could account for about 18.5% of the work performed.

Key words: hypoxia, anaerobic power, aerobic power, lactate.

RÉSUMÉ

La contribution aérobie au Test de Puissance Anaérobie Wingate (WAnT) a été évaluée chez cinq sujets masculins en mesurant la consommation d'oxygène ($\dot{V}O_2$) à chaque respiration. En présumant une efficacité mécanique optimale, le $\dot{V}O_2$ net durant le WAnT pourrait expliquer environ 18,5% du travail exécuté.

Mots clés: hypoxie, puissance anaérobie, puissance aérobie, lactate.

Introduction

There are conflicting data regarding the aerobic component of the Wingate Anaerobic Power Test (WAnT). Inbar et al. (1976) estimated the aerobic component to be 13% with a net oxygen consumption of 1.07 L over the 30 s test. Calculations using the data of Jacobs (1979) yield a similar aerobic contribution of 13.2%. In contrast, Stevens and Wilson (1986) reported a 44.3% aerobic contribution with a net oxygen consumption of 1.67 L. Such large differences require clarification before assuming that the WAnT is a valid means to evaluate the capacity to transduce energy via anaerobic metabolic pathways.

With one exception (Jacobs, 1979), the methodology used to determine oxygen uptake during the WAnT was not described in the studies referred to above, but it does not appear to have been done on a breath-by-breath basis (BxB) which would permit the study of the kinetics of oxygen uptake ($\dot{V}O_2$) as well as the aerobic component during the 30 s WAnT. To clarify the aerobic contribution to WAnT performance, the present study employed BxB monitoring of $\dot{V}O_2$ during performance of the WAnT.

Methods

The subjects were five healthy male volunteers whose mean ± SD age, weight and height were 26.4 ± 4.2 yrs, 76.2 ± 6.5 kg and 177.2 ± 11.5 cm, respectively. They performed the WAnT while breathing through a mouthpiece connected to an Alpha Technologies® metabolic cart (model MTS 4400). This metabolic cart is composed of an electrochemical yttria-stabilized zirconium-dioxide oxygen analyzer, with a range of 0–100%, and a non-dispersive infrared solid state carbon dioxide analyzer, with a range of 0–10% CO_2. Both analyzers are accurate to 0.03% and have a response time of <100 ms. Gas volumes are determined through a bi-directional turbine flow transducer with a range of 6–600 $L \cdot min^{-1}$. The samples are drawn at the subject's mouth during inhalation and exhalation at a rate of 100 times per second. The main computer is a Hewlett-Packard® series 200 model 16 (9816).

Each subject was given a warm-up, consisting of 5 min of cycling at 100 W, followed by a 1 min rest period prior to performance of the WAnT. The WAnT consisted of 30 s of pedalling at maximal frequency on a mechanically braked cycle ergometer (Cardionics®, Stockholm, Sweden) with resistance set

Table 1.
Breath-by-Breath Oxygen Consumption Data for One Subject During the Performance of the WAnT

Breath #	*Time* s	$\dot{V}_E$ $L \cdot min^{-1}$	*BR** min^{-1}	$\dot{V}O_2$ $mL \cdot min^{-1}$	$\dot{V}O_2$ $mL \cdot kg^{-1} \cdot min^{-1}$	$\dot{V}CO_2$ $mL \cdot min^{-1}$
1	01	132.9	79	1268	14.7	1480
2	02	64.5	76	757	8.8	780
3	03	70.9	77	832	9.7	917
4	03	126.9	83	868	10.1	1017
5	04	74.9	76	917	10.7	1101
6	05	85.5	68	1189	13.8	1522
7	06	83.7	64	1157	13.4	1559
8	07	36.0	78	318	3.7	644
9	07	88.5	110	1145	13.3	1244
10	08	71.1	67	864	10.0	1060
11	09	60.3	63	646	7.5	830
12	10	76.3	67	1075	12.5	1324
13	11	70.6	68	977	11.4	1086
14	12	75.1	62	1264	14.7	1387
15	13	80.9	53	1658	19.3	1764
16	14	84.6	42	2018	23.5	2111
17	16	70.8	40	1606	18.7	1647
18	17	74.8	38	1797	20.9	1873
19	18	154.7	75	3953	46.0	4020
20	19	156.0	73	4075	47.4	4242
21	21	91.3	34	2591	30.1	2755
22	22	159.2	57	4454	51.8	4885
23	23	166.0	62	4711	54.8	5198
24	24	163.8	61	4564	53.1	5055
25	25	174.0	61	5014	58.3	5617
26	26	160.5	57	4514	52.5	5180
27	27	166.9	57	4774	55.6	5532
28	28	143.2	65	3859	44.9	4502
29	29	151.4	67	4554	53.0	5195
30	30	148.4	67	4554	53.0	5200

*BR - breathing rate

so that one pedal revolution resulted in 4.4 $J \cdot kg^{-1}$ body weight. The number of flywheel revolutions, sensitive to 0.3 revolutions, was monitored electronically and converted into average power output for each 5 s during the WAnT.

An example of variables measured and reported by the Alpha Technologies® metabolic cart for one subject during the WAnT is shown in Table 1. The BxB $\dot{V}O_2$ for one subject, averaged over 5 s intervals, is plotted against elapsed time in Figure 1.

$\dot{V}O_2$ for each breath was determined by dividing the $\dot{V}O_2$, expressed in $L \cdot min^{-1}$, by the time interval between breaths; these results were summed to yield total $\dot{V}O_2$ for the 30 s time period. The net $\dot{V}O_2$ was determined for each individual assuming a resting $\dot{V}O_2$ of 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ (American College of Sports Medicine, 1980). The aerobic energy contribution to the WAnT was calculated for each subject from the net $\dot{V}O_2$ with a mechanical efficiency (ME) for the performance of a maximal

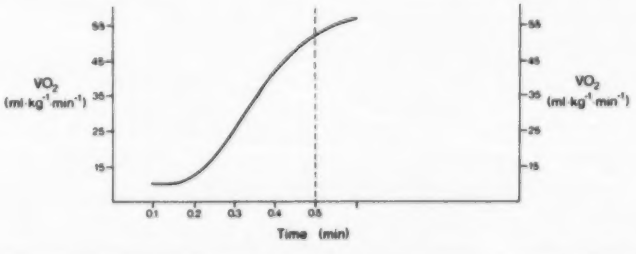

Figure 1. *Breath-by-breath data from one subject averaged over 5 s intervals during performance of the WAnT. The data were plotted and computer smoothed into a curve. Zero time indicates the beginning of exercise and the dashed vertical line indicates the end of exercise.*

Table 2.
Net Oxygen Uptake, % Aerobic Contribution and Total Work During Performance of the WAnT for 5 Subjects

Subject	$\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	*Net* $\dot{V}O_2$ (L)	*Work* (kJ)	*Aerobic Contribution* (%)	$\dot{V}O_{2max}$ *Attained* (%)
1	58.3	1.04	21.91	25.1	90.90
2	45.1	0.52	21.68	12.6	53.88
3	58.3	0.84	17.80	24.9	89.71
4	54.4	0.40	18.13	11.9	93.38
5	49.3	0.68	20.22	17.9	95.94
Mean	53.1	0.70	19.95	18.5	84.76
±SD	±5.8	±0.25	±1.93	±6.4	±17.43

Individual $\dot{V}O_{2max}$ and % $\dot{V}O_{2max}$ attained during the performance of the WAnT are also presented.

cycling test set at 25% (Gaesser and Brooks, 1975). The caloric equivalent of the $\dot{V}O_2$ was calculated assuming 100% carbohydrate oxidation (i.e. 5.05 $kcal \cdot L^{-1} \dot{V}O_2$) (Brooks and Fahey, 1984). The total energy demand for the work performed during the WAnT was calculated from the average power outputs during each 5 s of exercise. The aerobic contribution is expressed as a percentage of the energy required to cover the work performed during the WAnT.

Additionally, each individual's $\dot{V}O_2$ max was determined, on a different day from the WAnT test, using the Alpha Technologies[8] metabolic cart and a cycle ergometer. The subjects cycled at 60 rpm with a continuous incremental protocol beginning at 50 W. The power output increased by 50 W steps every 2 min until 150 W was attained and then 25 W every minute until exhaustion. Exhaustion was defined as an inability to maintain the prescribed rpm.

Results and Discussion

The individual data are shown in Table 2. The mean net $\dot{V}O_2$ is more consistent with the results of Inbar et al. (1976) and Jacobs (1979) than with Stevens and Wilson (1986). It is interesting to note that mean peak $\dot{V}O_2$ during the last five seconds of the WAnT reached 85 ± 17% of the $\dot{V}O_2$ max measured during the incremental exercise test. The individual data tempt the speculation that subjects with a higher $\dot{V}O_2$ max may be able to cover a greater proportion of the WAnT energy demand via aerobic metabolism than subjects with a lower $\dot{V}O_2$ max. This speculation is based on the work of Cerretelli et al. (1979) and Hickson et al. (1978), who demonstrated that steady-state $\dot{V}O_2$ is achieved more rapidly during submaximal exercise in endurance trained subjects than in control subjects.

Jacobs et al. (1987) demonstrated increased citrate synthase activity after repetitive training with the WAnT. In addition, Rotstein et al. (1986) demonstrated increased WAnT mean power in children who engaged in a nine-week endurance training program consisting of interval running and aerobic activities and games. These reports are indirect evidence of an aerobic component to the WAnT. Table 2 also lends support to the presence of a significant aerobic component to the WAnT; subjects with higher $\dot{V}O_{2max}$ values had larger relative aerobic contributions.

The mean aerobic contribution was about 18.5% of the work performed during the WAnT. It should be emphasized that our calculations assume the accepted ME for cycle exercise of 25% (Gaesser and Brooks, 1975). Recent estimations, however, during ,maximal isokinetic cycle exercise for 30 s based on measurements of ATP turnover suggest that ME could be as low as 13% (N. McCartney, personal communication 87/10/21). Recalculations using an intermediate ME of 20%, and this low ME of 13% commensurately lowered the mean ± SD aerobic contributions to 14.4 ± 5.2% and 9.4 ± 3.4% respectively.

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